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Ground-Based Thermographic Blade Inspection

Solving the Triple Constraints of Quality, Time and Costs

Ground-Based Thermographic Blade Inspection

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Thermal cameras with very high focal length were previously exclusively developed for space and defence applications. Now they are available for the civil market and bring to the wind energy sector higher quality and performance, lower Health, Safety and Environment risks and similar competitive prices to existing solutions. Based on the research work of institutes like the Sandia National Laboratories, the Federal Institute for Materials Research and Testing (BAM), Fraunhofer and private companies, the optical and thermographic inspection of wind blades becomes state of the art, so that certification bodies accept the ground-based thermographic inspection method as equivalent to the standard rope access method.

Thermography combined with optical visual imaging is revolutionising the wind blade inspection market by solving the triple constraints of quality, time and costs. The ground-based inspection method enables more efficient and predictable repair campaigns by documenting long-term fatigue behaviour of the blade structure and by providing transparency in quality from blade commissioning until end of lifetime

Figure 1. Thermographic technology now available for the wind blade inspection market

Thermography in the Wind Industry

The use of thermography in the wind industry is gaining momentum. The idea of seeing inside the blades from outside or of measuring the curing temperature during the manufacturing process is thrilling. The origin of thermography, however, is ancient and the first attempts to measure heat were made by Heron of Alexandria in the second century AD. The breakthrough came in 1800 when Sir William Hershel discovered a new spectrum of invisible light, now known as infrared. Due to the remarkable improvements in thermal imaging with special infrared sensors, new various applications were found, especially in the military and medical fields.

The Triple Constraints

In the last decade, companies in the wind industry have invested in this technology offering solutions also for the wind inspection market and manufacturing process. Famous institutes have shown how to use thermography to identify deviation of the material and structural elements. Several articles have been published describing the advantages of thermal imaging analysis of composite structures. Despite all the benefits and the growth of thermography, the wind industry has given this technology little space and acceptance so far. The fact is that there are many thermal cameras available in the civil market that do not deliver satisfactory results. On the other hand, the solutions available today capable of reaching high quality results are in many cases expensive or time consuming. The market is confronted with the triple constraints, also known as the magic triangle, in which a product or service can have only two of these three properties: cheap, fast and good.

From Sensor House to Thermographic Blade Inspection

The sensor specialist Hensoldt was founded from various former activities of Airbus Group in the areas of defence and security electronics and of Carl Zeiss in the area of optronics. The company has a large portfolio of thermal and optical camera systems, which were developed initially for defence and space applications. Several of these cameras are classified as dual use goods, enabling the company to target new markets, such as the inspection of composites. Due to its cutting-edge thermography, laser technologies and over 40 years' experience in outdoor and offshore applications, Hensoldt has decided to enter into the market of wind blade inspections and provide a novel inspection service: high quality, fast and cost-efficient optical and thermographic inspection from the ground (Figure 1).

Combination of Thermal and Visual Imaging

Optical, visual inspections are used to identify flaws on the blade surface. However, internal structural flaws such as delamination, wrinkles in the spar, or bonding issues can only be detected by thermal inspection methods, as shown in Figure 2. Resin nest, humidity in the core material, or dry laminate are typical findings. Surface cracks can have multiple origins, and it is seldom that they stay only on the surface. The thermal imaging technology provides a clear indication of

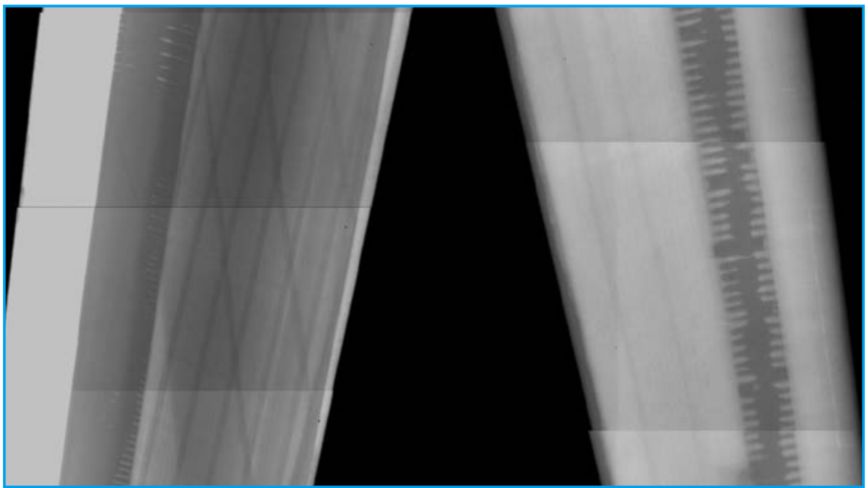

Figure 2. Detection of internal structural flaws through thermographic inspection

whether deeper damage is the root cause of the crack. On the other hand, dirt can produce false positive thermal detection. Therefore both technologies have their unique advantages and a combination of these two powerful technologies is required to achieve the best quality for the composite inspection and to detect a broader range of flaws. Figure 3 shows the limitations of traditional inspection with rope access. Only the combination of both optical (visual) and thermal imaging can cover the wide range of flaw types.

Surface Temperature Scanning

Some turbines are equipped with anti-icing systems and it is necessary to measure the absolute surface temperature to ensure the functionality of the de-icing system. The maximum temperature has to be measured to ensure that the blade is not damaged by overheating. In addition, the thermal scan ensures that no 'cold' areas are on the blade, so that the anti-icing system can really de-ice the blade on all areas. Thermal imaging for long-range systems is able to measure the absolute temperature over a distance of 100–200 metres and also under extreme weather conditions such as in the marine environment. For this purpose, a special algorithm and calibration units were developed for long-range application and are now available to guarantee very accurate thermal information over the entire rotor blade.

High Quality Thermal Imaging

To obtain the best results, a cooled high definition thermal camera is used with a very small noise equivalent temperature difference (NETD) of 0.025 kelvins. NETD is a measure of how well a thermal imaging detector is able to distinguish between very small differences in thermal radiation in the object observed. The camera lens has an aperture of 25 cm, and the focal length of the system is equivalent to 4,000 mm (calculated to small image format). The most common thermal camera systems available in the wind inspection market are uncooled. However, the Hensoldt camera technology is based on a cooled mid-wave detector (3.5–5 µm) to achieve the best performance for the thermal images. The camera system captures the thermal data with a pixel thermal resolution of 14 bits in the present range. This enables the system to show all thermal details. The use of optical and thermal high resolution camera systems with large focal length is the key to providing high quality imaging.

Lower Downtime for the Inspection

The camera system is placed at a distance approximately equal to the tower height plus blade length, i.e. ideally between a distance of 100 and 200 metres to the turbine. The optical and thermal cameras are mounted on a high precision pan tilt platform, while the blades are correctly positioned. The system scans the entire blade, i.e. the four sides of the blade: the pressure and suction side as well as the leading and trailing edge. One single operator needs approximately 70 minutes to inspect the three blades from the ground. For comparison reasons, a team of at least two climbers needs one whole day for inspecting the same number of blades. The flow of thermal energy from the surface to the core of the rotor blade is required for thermal imaging. Due to the high camera sensitivity, only the solar energy is used as the energy source, so that no other heating sources are needed, speeding up and lowering the cost of inspections. The system can be used during the entire year and also in cold weather. Due to its outstanding performance, this method of inspection was rated as being equivalent to the rope access method by the certification body DNV GL.

Lifetime Records for the Entire Blade

Thanks to a stitching program for optical and thermal imaging, a final analysis report is delivered with flaw localisation and severity classification. There is no need for second inspection, as the images are reproducible and reflect objectively the state of the blade. All data illustrating the entire blade are stored on a hard drive during the blade's lifetime. Images from blade commissioning, past inspections and previous repairs can be compared and deviations revealed from year to year. The tracking and ageing comparison are especially useful for periodic inspections and are essential in the decision-making process of blade lifetime extension. Repairs can be better scheduled, avoiding

		Inspection Methods		
		Rope access	HENSOLDT's solution	
			Optical	Thermal
Pollution		yes	yes	partially
Leading edge erosion		yes	yes	yes
Crack	visible on surface	yes	yes	partially
	crack caused by filler	no	no	yes
	crack caused by blister	no	no	yes
	crack caused by wrinkle	no	no	yes
Delamination		partially (tapping)	no	yes
Trailing edge bonding		partially	no	yes
Beam to shell bonding		no	no	yes
Vortex generator		yes	yes	yes
Resin channel		no	no	yes
Dry laminate		no	no	yes
Internal humidity		no	no	yes

Figure 3. Comparison of different inspection methods

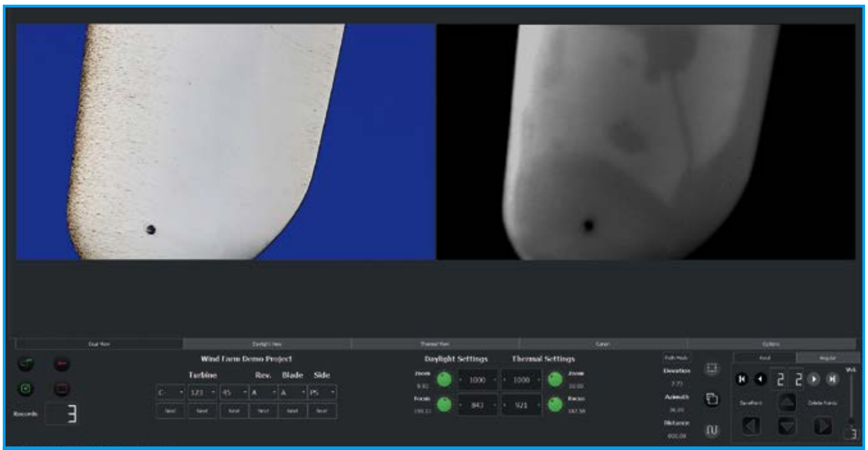

Figure 4. Optical and thermal scans from commissioning to the end of a blade's lifetime can extend blade operation and performance

short-notice repair actions, and also more precisely made and monitored.

Lower Cost at Minimal Risk

In addition to shorter inspection time and less weather restrictions, Hensoldt optical and thermographic inspection from the ground involves minimal Health, Safety and Environment (HSE) risks and almost no loss of energy yield. This impacts directly the overall costs for all involved parties. Nowadays with rope access and drone inspection methods, much effort (and money!) is put into complying with HSE regulations and to prevent material and physical injuries. Lowering the maintenance cost is the key to the successful and profitable operation of wind turbines. Digital thermal and optical inspection methods provide more information than traditional methods. Structural information for a depth deviation of several centimetres inside the composite material is visible and preserved for the entire lifetime of the wind turbine. ■

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